Nature of the Ordovician–Silurian boundary in south Kazakhstan, USSR

M. K. Apollonov[1], T. N. Koren[2], I. F. Nikitin[1], L. M. Paletz[1] and D. T. Tzai[1]

[1] Institute of Geology, Academy of Sciences of Kazakhstan SSR, Kalinina 69A, Alma-Ata 480100, USSR

[2] All-Union Geological Research Institute (VSEGEI), Sredni Prospekt 74, Leningrad 199026, USSR

Synopsis

Kazakhstan was the region where the coeval nature of the *Dalmanitina mucronata–Hirnantia* faunas with the *persculptus* Zone faunas was first established. The best sections are in the Chu-Ili Mountains of South Kazakhstan, the Ashchisu River and the Zhideli and Karasay sequences. A summary is given of the upper Ashgill and lower Llandovery biostratigraphy and the position of the systemic boundary. The lithostratigraphy is also outlined.

To have the Ordovician–Silurian boundary at the base of the *acuminatus* Zone was first advanced by Kazakhstan geologists (Rukavishnikova *et al.* 1968; Mikhailova 1970; Nikitin 1972; Apollonov *et al.* 1973; Apollonov 1974; Poltavtseva & Rukavishnikova 1972) after the discovery of *Glyptograptus persculptus* in association with *Dalmanitina mucronata* and *Hirnantia* in the Chu-Ili Mountains. This showed that the *persculptus* Zone did not succeed the *Dalmanitina* beds, as was previously thought in western Europe, and that, on the contrary, it was partly coeval with the *Dalmanitina mucronata–Hirnantia* beds which have always been assigned to the Ordovician. Thus it became clear that tracing the *persculptus* boundary in the neritic facies was impossible. This new evidence has been widely discussed in the literature (Williams *et al.* 1972; Bergström *et al.* 1973; Lespérance 1974; Rozman 1976; Rickards 1976).

The Kazakhstan Ordovician–Silurian boundary deposits are best studied in the Chu-Ili Mountains in south Kazakhstan, in the upper reaches of the Ashchisu River (Durben and Ojsu wells), as well as along the Zhideli and Karasay dry channels (Apollonov *et al.* 1980; Nikitin *et al.* 1980: textfigs 1–6). This paper is a summary of the upper Ashgill and lower Llandovery biostratigraphy and describes the position of the system boundary established in Kazakhstan on the basis of continuous sections.

The succession is divided into three conformable lithostratigraphic units: the Chokpar, Zhalair and Salamat Formations. The latter is overlain by the Betkainar Formation (Figs 1–6).

The Chokpar Formation consists of dark-grey and greenish-grey regularly bedded mudstones and siltstones yielding abundant graptolites characteristic of the *supernus* Zone (Apollonov *et al.* 1980). A more detailed zonation can now be suggested. The lowermost part of the Chokpar Formation contains *Dicellograptus ornatus minor* Toghill, *Climacograptus longispinus supernus* Elles & Wood, *Amplexograptus inuiti* (Cox) and *Orthograptus amplexicaulis* (Hall) and comprises the *inuiti* Zone. The graptolites present above this, and in most of the Chokpar Formation, are characteristic of the *pacificus* Zone and include *Dicellograptus ornatus* Elles & Wood, *Climacograptus manitoulinensis* Caley, *Orthograptus socialis* (Lapworth), *Paraorthograptus pacificus* (Ruedemann) (rare) and *Nymphograptus velatus* Elles & Wood. The uppermost Chokpar Formation locally contains limestone beds which are best developed in the Osju section where they are placed in a local stratigraphic unit—the Osju Limestones. The unit consists of dark-grey argillaceous limestones interbedded with aphanitic sandy limestones in which terrigenous clastics account for 15 to 20%. The Osju Limestones yields abundant brachiopods and trilobites including *Giraldiella bella* Bergström, *Streptis altosinuata* (Holtedahl), *Leptaena rugosa* Dalman, *Cryptothyrella* sp., *Tscherskidium* cf. *ulkuntasensis* Sapelnikov & Rukavishnikova, *Prostricklandia prisca* Rukavishnikova & Sapelnikov, *Platycoryphe sinensis sinensis* (Lu),

Fig. 1 Localities of the Ordovician–Silurian boundary deposits in Central and South Kazakhstan. 1, Sarysu–Teniz watershed and Zhaksykon River; 2, Northeast of Central Kazakhstan–Kombabasor lake; 3, Akjar–Zhartas watershed; 4–6, Chingiz Range and Pre-Chingiz Range: 4, Mount Otyzbes; 5, Mount Mizek; 6, Mount Akdombak; 7–12, Chu-Ili Mountains: 7, Karasay River; 8, Zhideli River; 9, Anzhar River; 10, Ojsu well; 11, Durben well; 12, Mount Dulankara.

Bumastus commodus Apollonov, *Decoroproetus artus* Apollonov, *D.* cf. *evexus* Owens, *Otarion curvulum* Apollonov, *O. gibberum* Apollonov, *Dicranogmus confinis* Apollonov, and *Leonaspis* sp. There also occur conodonts, bivalves, gastropods and cepalopods, among them *Acodus similaris* Rhodes, *Eobelodina fornicala* Stauffer, *Icriodella* sp., *Tshuiliceras lobatum* Barskov, *Michelinoceras procurens* Barskov and *Geisonoceras fustis* Barskov.

The numerous graptolites that are characteristic of the *pacificus* Zone occur in argilliceous limestone layers. Present are *Climacograptus longispinus supernus* Elles & Wood, *C.* cf. *normalis* Lapworth, *C. tatianae* Keller, *Glyptograptus posterus* Koren & Tzai, *G.*? *ojsuensis* Koren & Mikhailova, *Paraorthograptus pacificus* (Ruedemann), *Orthograptus amplexicaulis* (Hall) and *Plegmatograptus nebula lautus* Koren & Tzai. Rare tabulate corals, radiolarians and algae are also known (Apollonov *et al.* 1980).

The uppermost Chokpar Formation in other sections (as at the Anzhar River) is represented by massive biogenic-detrital limestones (the so-called Ulkuntas Limestones) overcrowded with tabulate corals and heliolitids. The assemblage includes *Agetolites* cf. *mirabilis* Sokolov, *Hemiagetolites insignis* Poltavceva, *Catenipora inordinata* Kovalevsky, *Plasmoporella papillatiformis* Kovalevsky, *Propora cancellatiformis* Sokolov and *Heliolites parvulus* Kovalevsky. Some pentamerids such as *Holorhynchus giganteus* Kiaer, *Proconchidium tchuilensis* Rukavishnikova & Sapelnikov and *Tcherskidium*? *ulkuntasense* Rukavishnikova & Sapelnikov have been found. There occur the trilobites *Holotrachellus punctillosus* Törnquist, *Amphylicas* sp. and *Sphaerexochus* sp., which are characteristic of biohermal environments. The thickness of the Ojsu and Ulkuntas Limestones varies from 14 to 55 m and the Chokpar Formation totals 140 to 180 m.

The Zhalair Formation rests conformably on the Chokpar deposits and is exposed in all sections studied. The section at Durben may serve as a stratotype (Figs 2, 3). The formation is composed of tobacco-green and greenish-grey siltstones interbedded locally with grey and reddish-brown fine-grained poorly sorted sandstones, the latter being of carbonate and quartz-feldspathic composition. Locally, sandstones form a separate unit more than 80 m thick, for example at the Ojsu section. The lowermost Zhalair Formation includes the Durben Limestone which is 9 to 40 m thick, and is easily discernible in many of the sections studied (Fig. 4). It consists of well-bedded dark grey pelitomorphic limestones. The upper part of the Zhalair Formation contains local beds of dark grey and green silty tuffites.

The lower Zhalair Formation (the Durban horizon) contains graptolites of the *extraordinarius* and *persculptus* Zones (Koren & Nikitin 1983). The former zone yields *Climacograptus angustus* (Perner), *C. normalis* Lapworth, *C.*? *extraordinarius* (Sobolevskaya) (= *Glyptograptus*? *persculptus* forma A and *G.* aff. *persculptus* of Apollonov *et al.* 1980) and *Pseudoclimacograptus*

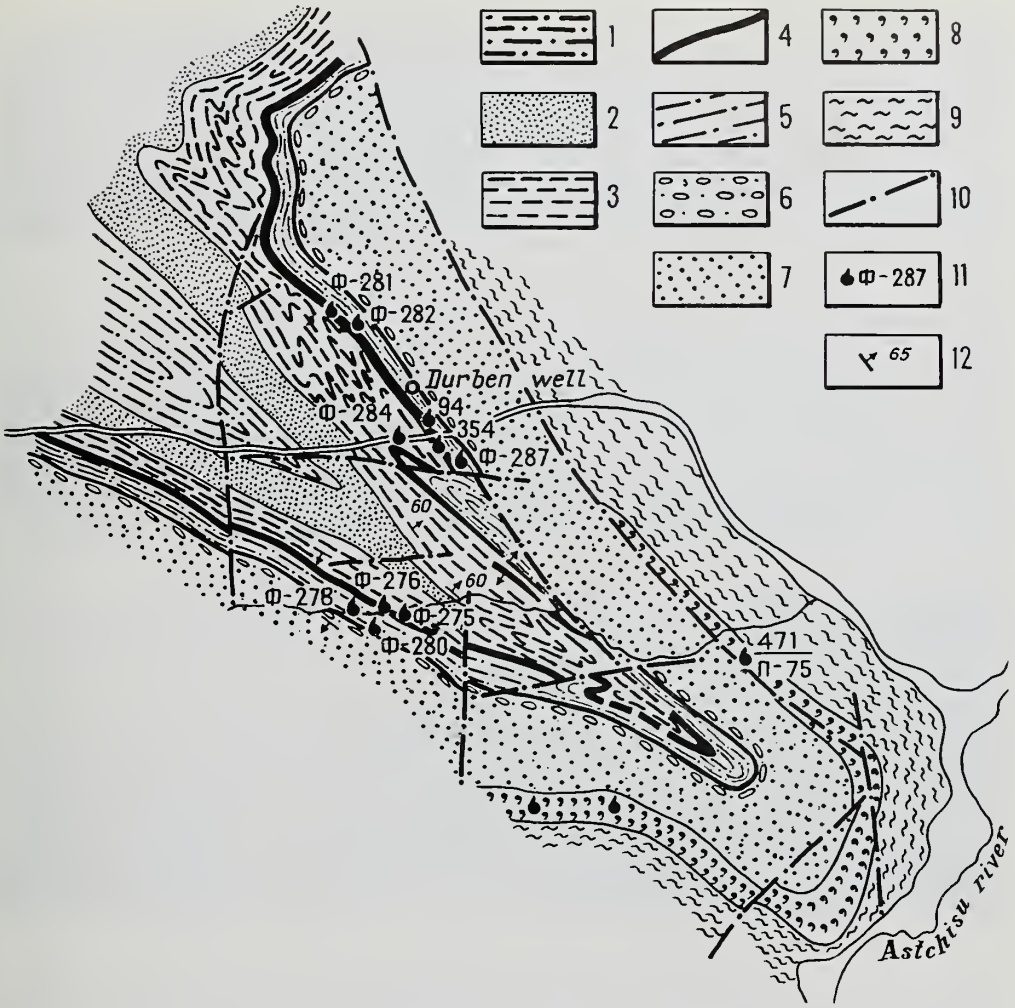


Fig. 2 Schematic geological map of the Durben well area. 1, 2, Kysylsai Formation (?): 1, black siltstones and sandstones; 2, yellow sandstones; 3, Chokpar Formation black mudstones and siltstones; 4, 5, Zhalair Formation: 4, dark fine-crystalline and fine-clastic limestones; 5, green siltstones and fine-grained sandstones; 6, 7, Betkainar Formation: 6, basal conglomerate and sandstones; 7, grey sandstones; 8, red sandstones; 9, Koichin Formation: red sandstones and siltstones; 10, faults; 11, localities of fauna; 12, strike and dip.

sp. The latter zone may be distinguished by the occurences of *Glyptograptus persculptus* (Salter) (=*G. persculptus* forma B of Apollonov *et al.* 1980), *Glyptograptus* sp. and *Climacograptus angustus* (Perner). A shelly fauna was found in limestones and siltstones within both graptolite zones, namely a typical *Dalmanitina–Hirnantia* assemblage including *Platycoryphe sinensis* (Lu), *Dalmanitina mucronata* (Brongniart), *Dalmanitina olini* Temple, *Leonaspis olini* Troedsson, *Dicranopeltis* sp., *Dalmanella testudinaria* (Dalman), *Hirnantia sagittifera* (M'Coy), *Anisopleurella novemcostata* Nikitin, *Aegiromena durbenensis* Nikitin, *Aphanomena ultrix* (Marek & Havlíček), *A.* aff. *urbicola* (Marek & Havlíček), *Bracteoleptaena polonica* Temple, *Eostropheodonta bublitschenki* Nikitin and *Coolinia iliensis* Nikitin.

Fig. 3 A—Section on the north-east limb of the Ashchysu anticline near the Durben well. (a) the Chokpar Formation, (b–d) the Zhalair Formation: (b) limestones, (c) carbonaceous sandstone, (d) limestones, (e) siltstones, (f) Betkainar Formation; 354, f-287—localities of fauna. In the background to the right are hills composed of coarse-grained sandstones of Betkainar Formation on the south-western limb of the anticline.

B—enlarged part of the same section.

C—section near the Ojsu well. (a) Ojsu Limestones of the uppermost part of the Chokpar Formation; (b) limestones with *Dalmanitina* assemblage; (c) siltstone of the basal Silurian. In the foreground an exposure of the Ojsu Limestones is seen.

D—transgressive onlapping of the basal conglomerate of the Betkainar Formation (b) on siltstones of the middle Zhalair Formation (a) in the Durben well area. Photographs I. F. Nikitin.

The thickness of the lower Zhalair Formation (the *extraordinarius* and *persculptus* Zones) varies from 122 to 127 m in the southeastern Chu-Ili Mountains (the Durben and Osju wells), to 55 m in the Zhideli River and to half a metre in the Karasay River in the northwestern Chu-Ili Mountains.

The upper Zhalair Formation (the Alpeis horizon) yields early Silurian graptolites. The *acuminatus* Zone is well defined in the strata overlying the *persculptus* Zone in sections in the Karasay, Zhideli, and Ashchysu Rivers. The zonal assemblage includes abundant graptolites, namely *Climacograptus acceptus* Koren & Mikhailova, *C.? jidelensis* Koren & Mikhailova, *C. mirnyensis* (Obut & Sobolevskaya), *C.* ex gr. *normalis* Lapworth, *Pseudoclimacograptus* (*Metaclimacograptus*) *fidus* Koren & Mikhailova, *P.* (*M.*) *pictus* Koren & Mikhailova, *Diplograptus modestus primus* Mikhailova, *G. madernii* Koren & Tzai, *Akidograptus* cf. *ascensus* Davies, *A. ascensus cultus* Mikhailova, *Parakidograptus* cf. *acuminatus* (Nicholson) and *Orthograptus illustris* Koren & Mikhailova.

The younger beds of the Zhalair Formation are eroded over most of the area studied (Fig. 4) and they are exposed only in the lower Karasay River. There, in beds overlying the *acuminatus* Zone, the graptolites *Climacograptus miserabilis* Elles & Wood, *Glyptograptus* sp. and abundant *Priblylograptus* sp. and *Atavograptus* sp., characteristic of the *vesiculosus* Zone, were found. The section is capped by strata yielding *Climacograptus angustus* (Perner), *C. mirnyensis* (Obut & Sobolevskaya), *C. normalis* Lapworth, *Pseudoclimacograptus* (*Metaclimacograptus*) *hughesi* (Nicholson), *Coronograptus cyphus* (Lapworth), *C. gregarius* (Lapworth), *Monograptus revolutus praecursor* Elles & Wood, *Atavograptus* sp. and *Dimorphograptus dessicatus* Elles & Wood. Shelly fauna is scarce in the Silurian part of the Zhalair Formation. In the *acuminatus* Zone only a single trilobite of the family Odontopleuridae occurs (exposure 280). The Zhalair Formation is 51 to 133 m thick.

The Salamat Formation consists of green sandstones and siltstones with abundant graptolites of the *gregarius* Zone. The overlying Betkainar Formation, with basal conglomerate beds, transgresses deposits of different ages, including in places the *Dalmanitina mucronata* beds of the Durben horizon (Figs 2, 4).

The Ordovician–Silurian boundary in the Chu-Ili Mountains is drawn at the base of the *acuminatus* Zone, which is marked by the appearance of *Akidograptus ascensus* Davies, *Glyptograptus madernii* Koren & Tzai, *Orthograptus illustris* Koren & Mikhailova and *Diplograptus modestus primus* Mikhailova.

The Chokpar and Zhalair Formations reflect a distinct regressive-transgressive cycle (Fig. 5). Dark pelitomorphic deposits of the Chokpar Formation (the *supernus* Zone) are comparatively deep-water and might have accumulated in an extensive, open, flat-bottomed sea with a remote source of terrigenous sediments. That sea was inhabited by diverse graptolites (more than 15 species). Towards the end of Chokpar time, the sea bed was elevated and a number of bioherms chains were developed. Each bioherm had a trail of clastic carbonate material (the Ulkuntas Limestones).

In early Durben time (the *extraordinarius* Zone), the areas of continuously growing elevation were surrounded by thick beds chiefly consisting of limey coarse-grained sands (Fig. 6), and a broad band of the fine dark Durben Limestones accumulated which were 40 m thick near the elevations and 0·5 m thick further away. The areas of limestone sedimentation were inhabited by a trilobite assemblage including *Dalmanitina mucronata*, *D. olini* and *Platycoryphe sinensis*. In the deep-water limestones near the village of Karasay a single species of blind *Dalmanitina* was found. Brachiopods are commonly represented by the single species *Bracteoleptaena polonica*. The graptolite assemblage consists of 2 to 4 species, and all the fossils are large-sized, numerous but taxonomically restricted. Late Durben time (the *persculptus* Zone) saw the deposition of green fine-grained sandstones and cross-bedded siltstones with traces of turbidity and slumping. The benthic fauna shows a greater diversity (the *Hirnantia–Dalmanitina* assemblage) but the graptolites are limited to two to three species.

An abrupt increase in the supply of tuffaceous material coincided with the beginning of the *acuminatus* Zone. A new and diverse (up to 15 species) graptolite assemblage appeared; however, benthic faunas are almost unknown from this level. The cosmopolitan distribution of

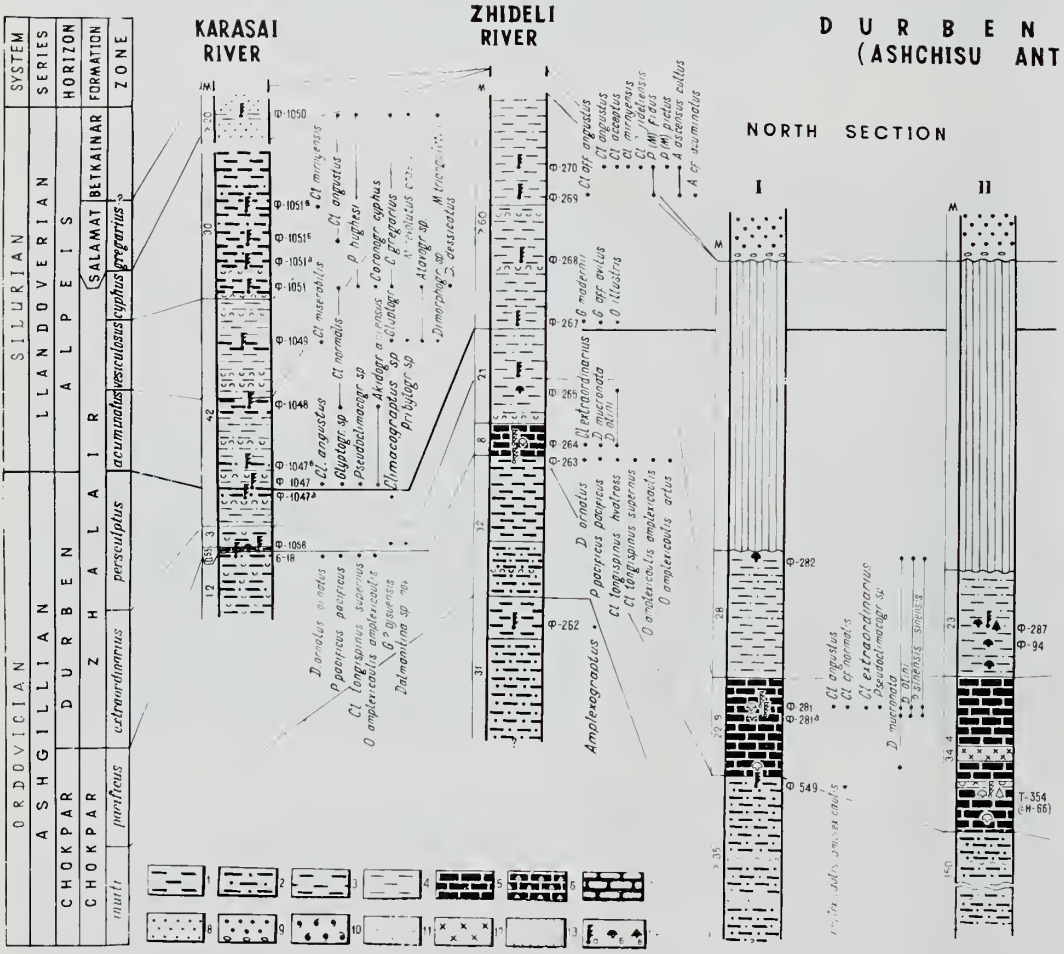
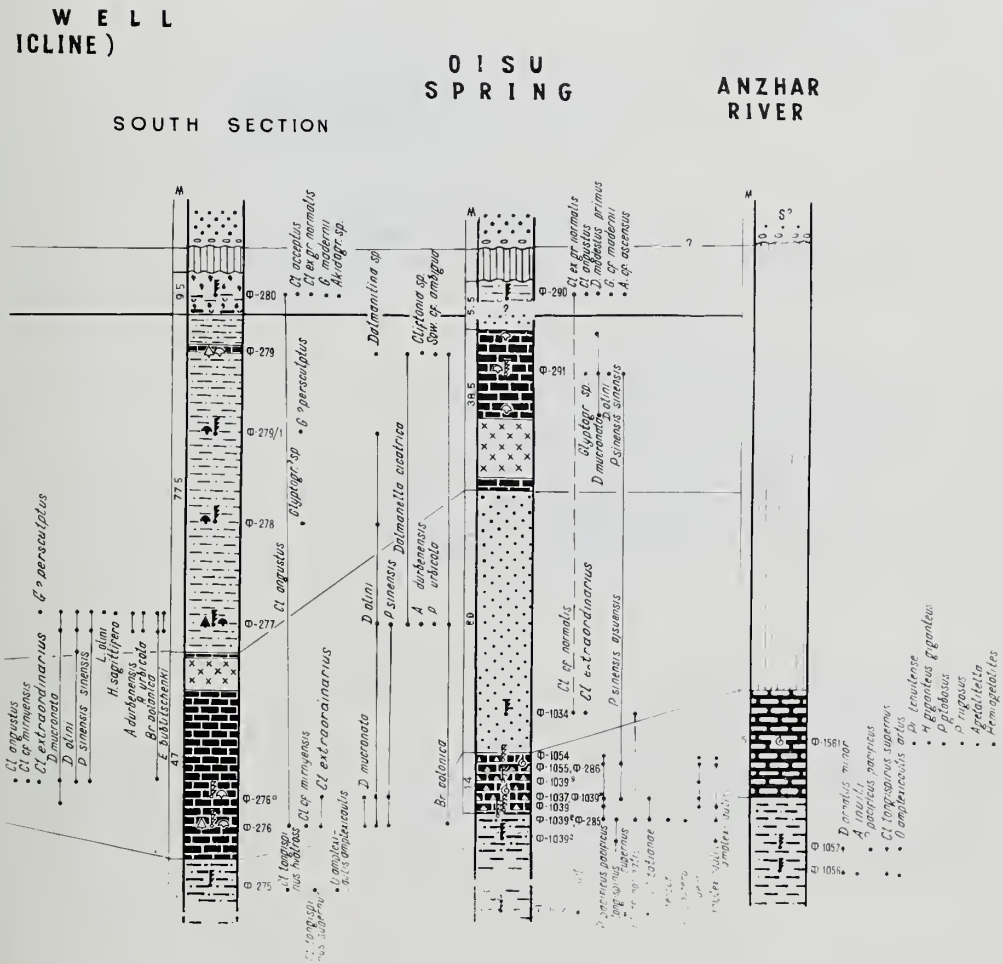


Fig. 4 Chart showing a correlation of the Ordovician–Silurian boundary deposits in the Chu-Ili Mountains. 1, black mudstones, siltstone and silty mudstones; 2, dark grey to black mudstone and siltstone; 3, grey tuffaceous pelite, tuffaceous mudstone; 4, grey siltstone, mudstone, fine-grained sandstone; 5, dark grey fine-crystalline evenly bedded limestone, sometimes clayey; 6, detrital



limestone; 7, bioherm limestone; 8, middle and coarse-grained polymictic sandstone; 9, conglomerates and coarse-grained polymictic sandstones; 10, tuffaceous sandstone; 11, fine-clastic acid tuff and tuffite; 12, diorite sill; 13, non-deposition; 14, fossils: (a) graptolites, (b) trilobites, (c) brachiopods.

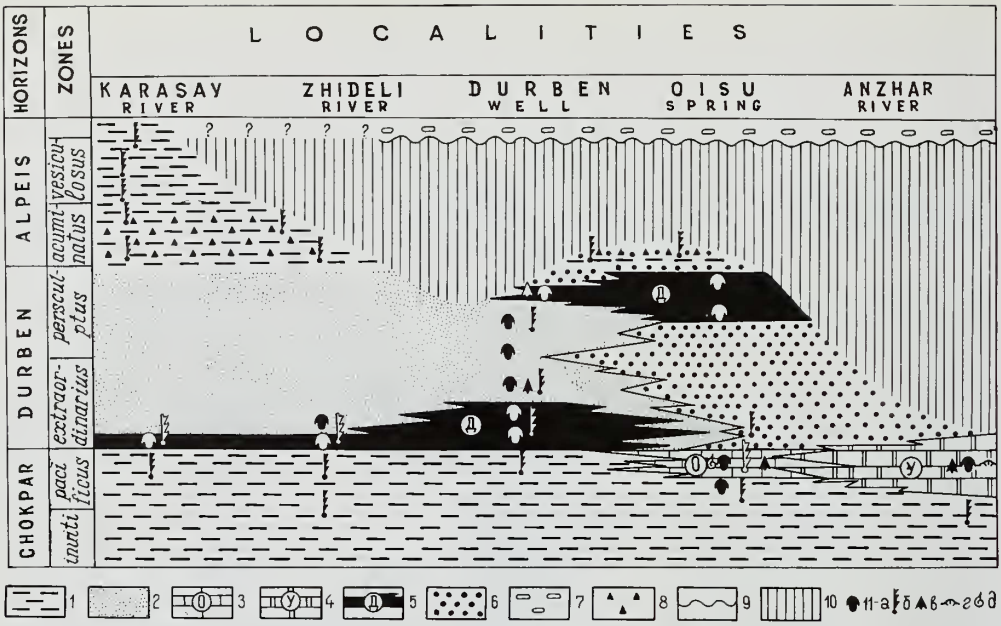


Fig. 5 Chart showing the lateral variation of different lithogenetic types within the Ordovician–Silurian boundary interval in South Kazakhstan. D, Durben Limestones; O, Ojsu Limestones; U, Ulkuntas Limestones. 1, black mudstones; 2, green sandstone; 3, detrital thin-bedded microcrystalline limestone; 6, sandstone; 7, conglomerate and gritstone; 8, tuffite; 9, unconformity; 10, non-deposition; 11, fossils: (a) trilobites, (b) graptolites, (c) brachiopods, (d) corals, (e) other fauna groups.

the *acuminatus* graptolite assemblage may be due to the widespread early Llandovery transgression. A great crisis in graptolite evolution within the *extraordinarius* and *persculptus* Zones took place at the end of the Ordovician regressive cycle.

The basal lower Silurian deposits (the *acuminatus* Zone) outside the Chu-Ili Mountains are established in eastern Central Kazakhstan in the Otyzbes Mountains, near the Kombabasor Lake east of the town of Bajanaul and at the watershed of the Akzhar–Zhartas Rivers northeast of Karaganda (Bandaletov 1969; Apollonov *et al.* 1980; Fig. 1 herein).

The uppermost Ashgill deposits (the *Dalmanitina mucronata* beds of the Durben horizon) are known from the Zhaksykon River basin at the Sarysu–Teniz watershed in the Chingiz Range (near the town of Akdombak) and south-western Chingiz area (Nikitin 1972; Nikitin *et al.* 1980). The systemic boundary in the regions within the neritic development is defined by the appearance of the diagnostic brachiopods *Eospirifer cinghizicus* and *Holorhynchus cinghizicus* and tabulate corals (Borisyak *et al.* 1969; Nikitin 1972).

However, direct correlation between the graptolite and shelly sequences within the Silurian basal beds is still not fully established, and the problem of the identification of shelly faunas diagnostic of the *acuminatus* Zone remains open in Kazakhstan as elsewhere.

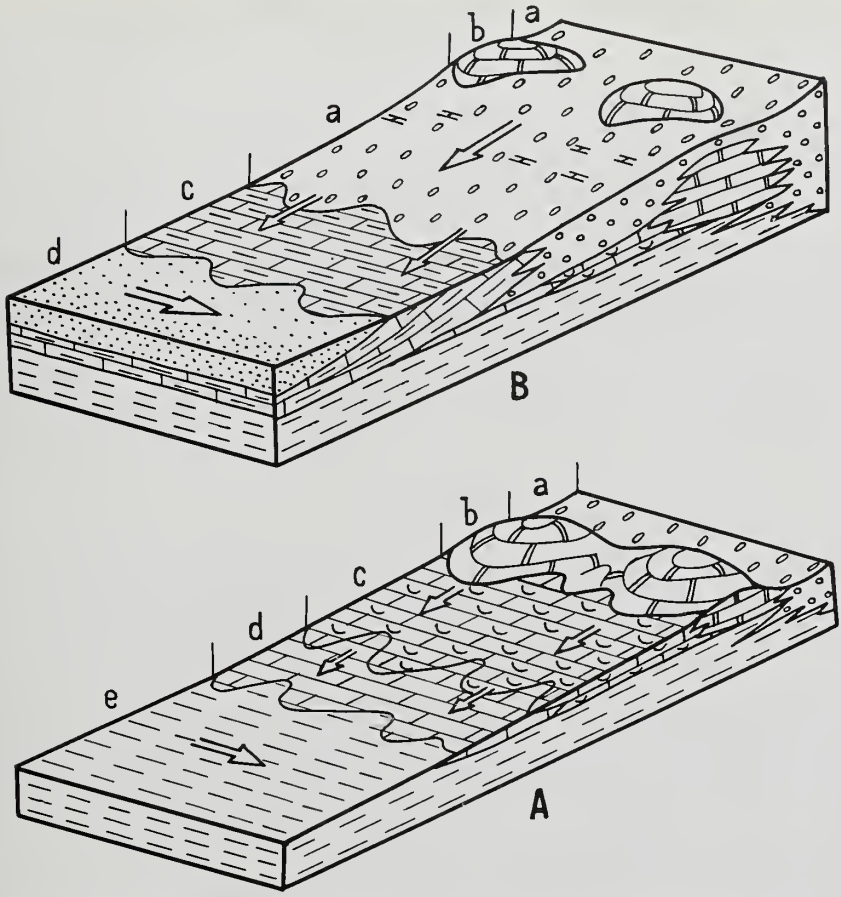


Fig. 6 Schematic depositional patterns in the South Kazakhstan Palaeo-basin in the uppermost Ordovician. A (*supernus* Zone): a, coarse sandstones; b, biohermal (Ulkuntas) limestones; c, detrital (Ojsu) limestone; d, microitic (Ojsu) limestone; e, black (Chokpar) mudstones.
B (*extraordinarius* and *persculptus* Zones): a, coarse sands; b, biohermal limestones; c, thin-bedded micritic (Durben) limestones with *Dalmanitina* association; d, fine sandstones with *Dalmanitina–Hirnantia* association.
Arrows indicate the direction of transport of the clastic material.

References

Apollonov, M. K. 1974. *Ashgillskie trilobity Kazakhstana* [*Ashgill trilobites in Kazakhstan*]. 136 pp. Alma-Ata.

——, **Bandaletov, S. M. & Nikitin, I. F.** (eds) 1980. [*The Ordovician–Silurian boundary in Kazakhstan*]. 300 pp. Alma Ata. [In Russian].

——, ——, ——, **Paletz, L. M. & Tzai, D. T.** 1973. K probleme granitzy ordovika i silura v Chu-Ilijskikh gorakh (Jzhny Kazakhstan) [On the Ordovician–Silurian boundary in Chu-Ili Mountains, South Kazakhstan]. *In: Informatsionny sbornik nauchno-issledovatel'skikh rabot* [for **1972**]: 23–25. Alma-Ata, Nauka.

Borisyak, M. A., Kovalevski, O. P. & Nikolaeva, T. V. 1961. K stratigrafii silura khr. Chingiz [On the Silurian stratigraphy in the Chingiz Range]. *Informatsionny sb. VSEGEI* **2:** 61–69.

Keller, B. M. 1956. Obschij obzor stratigrafii ordovica Chu-Ilijskikh gor [General review of the Ordovician stratigraphy in the Chu-Ili Mountains]. *In: Ordovik Kazakhstana*: 5–49. Izdatel'stvo Akad. Nauk SSSR.

Koren, T. N., Sobolevskaya, R. F., Mikhailova, N. F. & Tzai, D. T. 1979. New evidence on graptolite succession across the Ordovician–Silurian boundary in the Asian part of the USSR. *Acta palaeont. pol.*, Warsaw, **24:** 125–136.

—— **& Nikitin, I. F.** 1983. Comments on the definition of the Ordovician–Silurian boundary. *Eesti NSV Tead. Akad. Toim.*, Tallinn, (Geol.) **32** (3): 96–100.

Lespérance, P. J. 1974. The Hirnantian fauna of the Percé area (Québec) and the Ordovician–Silurian boundary. *Am. J. Sci.*, New Haven, **274:** 10–30.

Mikhailova, N. F. 1970. O nakhodke *Glyptograptus persculptus* (Salter) v dal'manitinovykh sloyakh Kazakhstana [On the occurrence of *Glyptograptus persculptus* (Salter) in the *Dalmanitina* beds of Kazakhstan]. *Eesti NSV Tead. Akad. Toim.*, Tallinn, (Khim. Geol.) **19:** 177–178 [In Russian with Engl. summ.].

Nikitin, I. F. 1971. The Ordovician system in Kazakhstan. *Mém. Bur. Rech. géol. minière.*, Paris, **73:** 337–343.

—— 1976. Ordovician–Silurian deposits in the Chu-Ili mountains (Kazakhstan) and the problem of the Ordovician–Silurian boundary. *In* M. G. Bassett (ed.), *The Ordovician System*: 292–300. Cardiff.

——, **Apollonov, M. K., Tzai, D. T. & Rukavishnikova, T. B.** 1980. Ordovikskaja sistema [The Ordovician system]. *In*: *Chu-Ilijskii rudnyi poyas. Geologia Chu-Ilijskogo regiona*: 44–78. Alma-Ata.

Poltavtseva, N. V. & Rukavishnikiva, T. B. 1973. Granitsa ordovikskoj i silurijskoj sistem v Chu-Ilijskikh gorakh [The Ordovician–Silurian boundary in the Chu-Ili Mountains]. *In*: *Materialy po geologii i poleznym iskopaemym Yuznogo Kazakstana*: 28–38. Alma-Ata.

Rickards, R. B. 1976. The base of the Silurian System in the British Isles. *In*: *Graptolity i stratigrafia*: 152–153. Tallinn, Valgus.

Rozman, K. S. 1976. Granitsa ordovika i silura [The Ordovician–Silurian boundary]. *In*: *Granitsy geologicheskikh sistem*: 72–93. Moscow, Nauka.

Rukavishnikova, T. B., Tokmacheva, S. G. & Salin, B. A. 1968. Novye dannye po stratigrafii otlozhenii verkhnego ordovika i nizhnego silura Chu-Ilijskikh gor [New evidence on the upper Ordovician–lower Silurian stratigraphy in Chu-Ili Mountains]. *Dokl. Akad. Nauk SSSR*, Leningrad, **183:** 420–423.

Williams, A., Strachan, I., Bassett, D. A., Dean, W. T., Ingham, J. K., Wright, A. D. & Whittington, H. B. 1972. A correlation of Ordovician rocks in the British Isles. *Spec. Rep. geol. Soc. Lond.* **3.** 74 pp.